

Conservation Genetics – Dynamic and Adaptive Discipline

- Phylogenetics
- Phylogeography
- Population Genetics
- Landscape Genetics
- Community Genetics
- Ecological Genomics
- Genetic Engineering

Identification of the basic unit of management

Regardless of objective (**RESTORATION** or **ERADICATION**) must identify the basic unit of management.

Molecular genetic techniques combined with new statistical analyses provide a robust set of tools for delineating the appropriate unit of management.

Contemporary molecular genetics allows research at the finest level possible - the **unique multilocus genotype**.
Witnessing somewhat of a paradigm shift - away from the population as the OTU (operational unit).

Individual-Population-Species Continuum

DNA sequence analysis: targets taxonomic or phylogeographic (i.e., *Species*) end of the spectrum.

Microsatellite DNA and allozyme analyses: target the *Individual-Population* end.
[Fine-brush]

Molecular Systematics

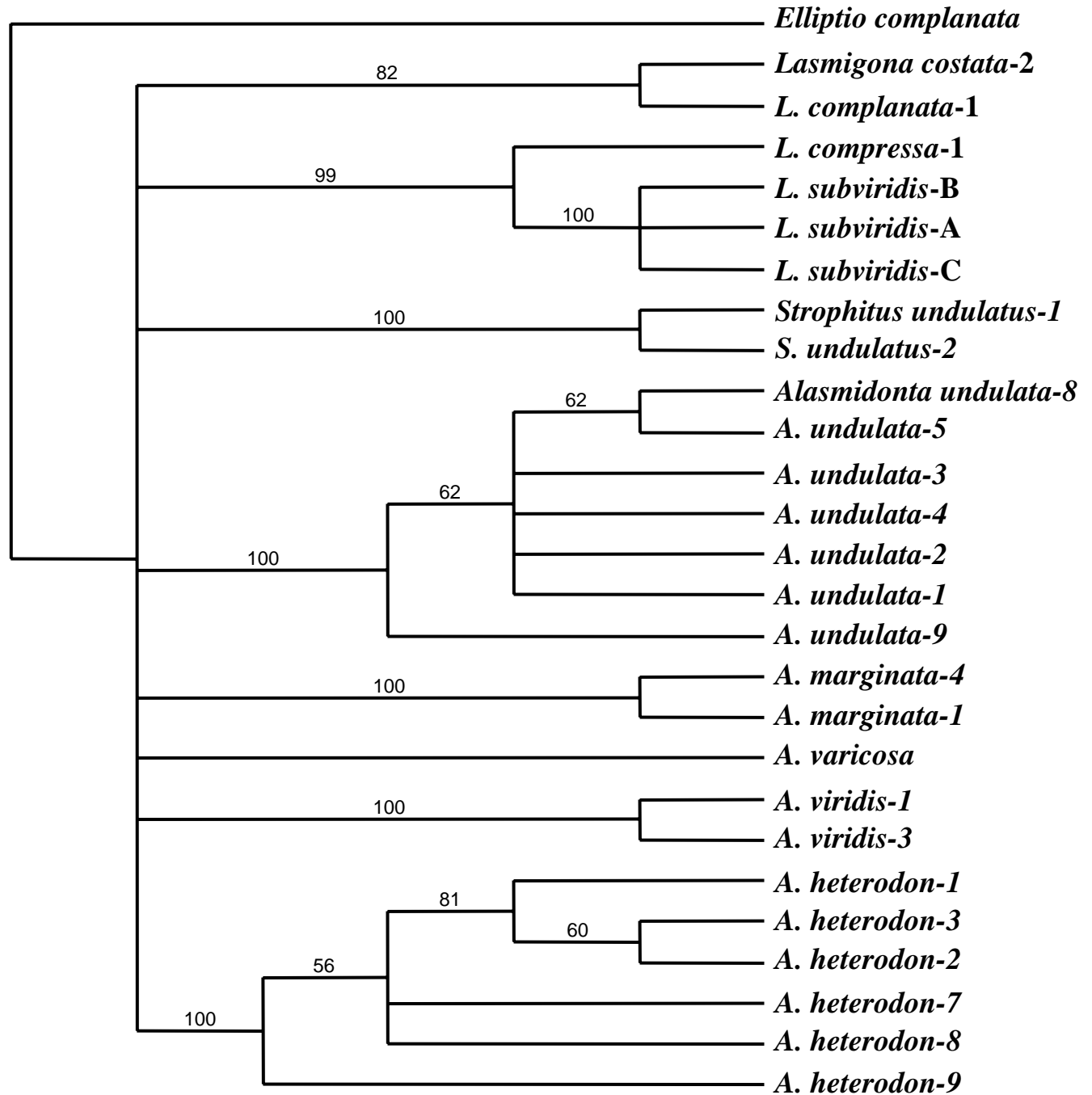
Detection, description, and explanation of molecular diversity, both within and among species

systematics + evolutionary theory + molecular genetics

Reconstructing evolutionary history based on shared attributes of extant and fossil organisms

Alasmidonta

COI
MP Tree



Phylogeography

(Avice 1987)

Comparison of *phylogenies* of populations or species with their geographic distributions

phylogenetics + population genetics + biogeography

Most common uses – delineate distinct population segments
gene flow
effective population sizes
evolutionary trajectories

darter

Asperella asprella

Phylogenetic Tree:

- Root:** 100
- Branch 1 (67):**
 - Branch 2 (100):**
 - Branch 3 (99):**
 - Cahaba 19
 - Cahaba 18
 - Cahaba 17
 - Cahaba 22
 - Cahaba 21
 - Branch 4 (97):**
 - Pearl 26
 - Pearl 25
 - Pearl 24
 - Pearl 23
 - Pearl 27
 - Branch 5 (100):**
 - Zumbro 11
 - Zumbro 12
 - Zumbro 13
- Branch 6 (100):**
 - Saline 09
 - Saline 06
 - Saline 08
 - Saline 07
 - Saline 10
- Branch 7 (100):**
 - Elk 05
 - Elk 02
 - Elk 03
 - Elk 04

Geological Time Scale:

- Pliocene:** A, B
- Pleistocene:** C

Geographic Regions:

- Gulf Coastal Plain:** Cahaba 19, 18, 17, 22, 21; Pearl 26, 25, 24, 23, 27
- Glacial Till Plains:** Zumbro 11, 12, 13
- Ouchita Highlands:** Saline 09, 06, 08, 07, 10
- Eastern Highlands:** Elk 05, 02, 03, 04

% Sequence Divergence: 5.0, 4.0, 3.0, 2.0, 1.0, 0.0

Population Genetics

Assess baseline levels of genetic diversity

Population structure – stock identification

Identify previously undetected structure

Assess levels of gene flow

Estimate effective population sizes

Enhanced assignment test results

Captive breeding management

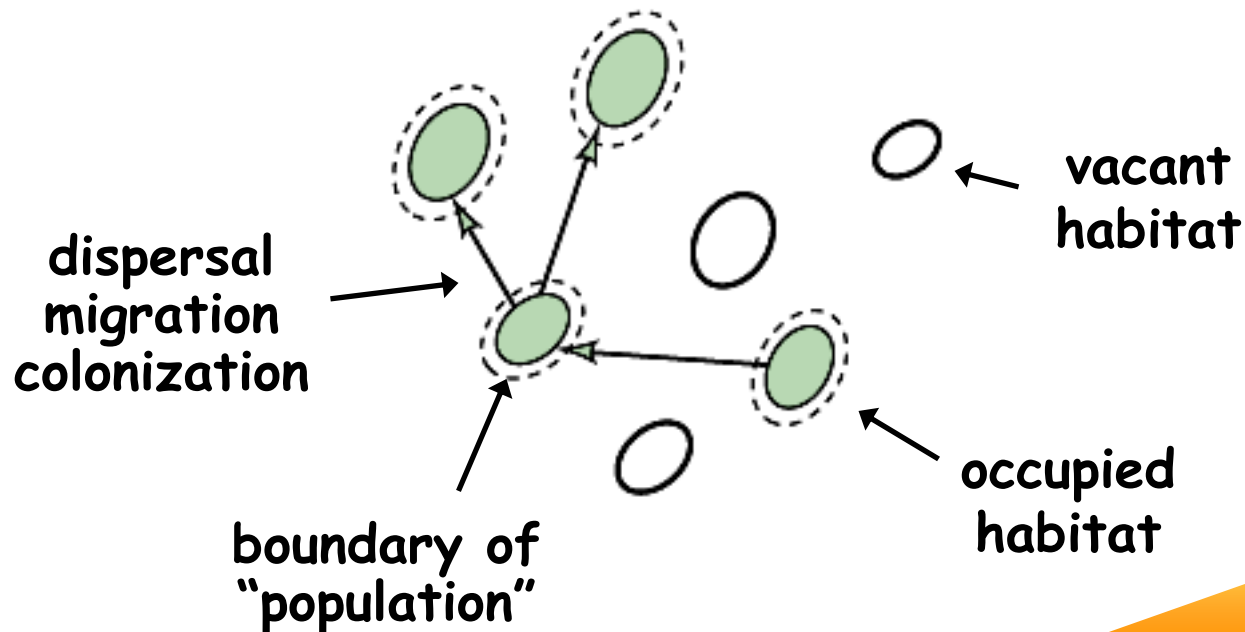
Mark-recapture

Models of Population Structure

Metapopulation

A group of small, separate populations or subpopulations, maintained by the balance between colonization and (local) extinction

Landscape / environment is not homogeneous; suitable habitat is patchily distributed



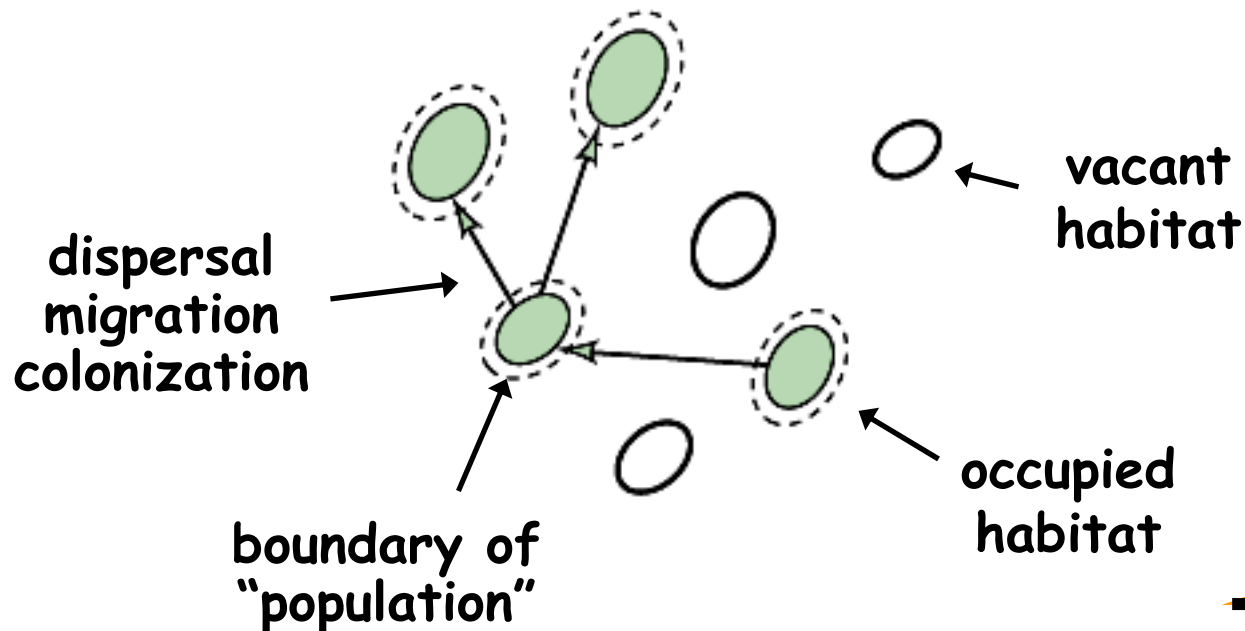
Metapopulations

Dynamics depend on inter-patch distance, dispersal ability, number of patches

Consequences:

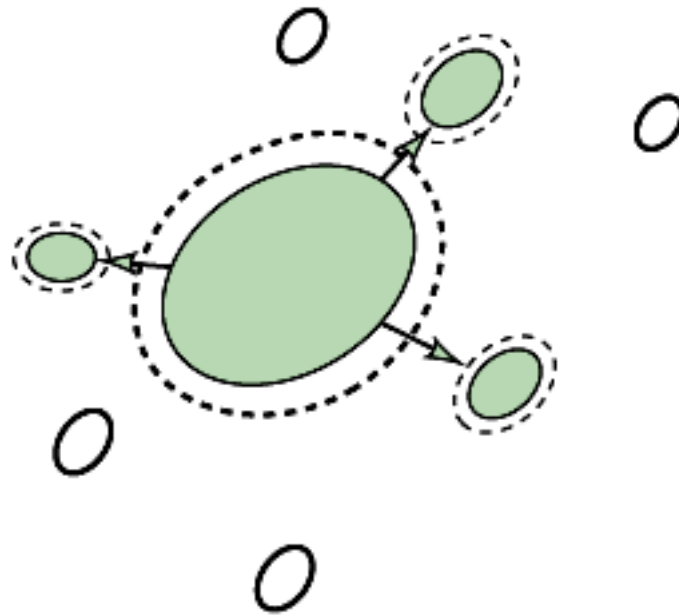
- can increase the persistence time of the entire population on the landscape

Collapses if number of patches becomes too small



Metapopulations

Few natural systems fit the classic description of a metapopulation. Instead, many are actually variations on a theme:



source-sink

What is Landscape Genetics?

Population structure reflects the dynamics (directed and stochastic processes) of the species' interactions with its environment.

Traditional population genetic analyses can provide useful information (phylogeographic structure, demographic information) but are often not the most appropriate for use in detecting fine-scale structure.

Contemporary molecular genetics allows researchers to focus at the finest level possible - the **unique multilocus genotype**.

What is Landscape Genetics?

Robust statistical tools applied to unique multilocus genotypes can allow the identification of fine-scale spatial genetic patterns.

These patterns will be compared with landscape or environmental features (including robust distance metrics and numerous data Layers) made available by landscape ecologists to identify the most basic unit of management.

Population/Individual Genetics + Landscape Ecology = Landscape Genetics

unique genotypes
genetic distances

distance metrics
GIS data layers

robust statistical analyses

Landscape Genetics Examples

- Vernal pool-breeding amphibians (mapped to pond)
 - Jefferson salamander
 - Spotted salamander
 - Wood frogs
- Key Largo Woodrats
- Nutria
- Black bear
- Kirtland's warbler
- Any study that involves the generation of unique multilocus genotypes and incorporates the use of GPS (or Seabeam) data to record collection site.

What is Community Genetics?

- “The analysis of evolutionary genetic processes that occur among interacting populations in communities” (Antonovics 1992).
- Study of the role of intraspecific genetic variation in **DOMINANT** and **KEYSTONE** species, which in turn affects dependent species, community organization, and ecosystem dynamics.

Why do we need a community genetics perspective?

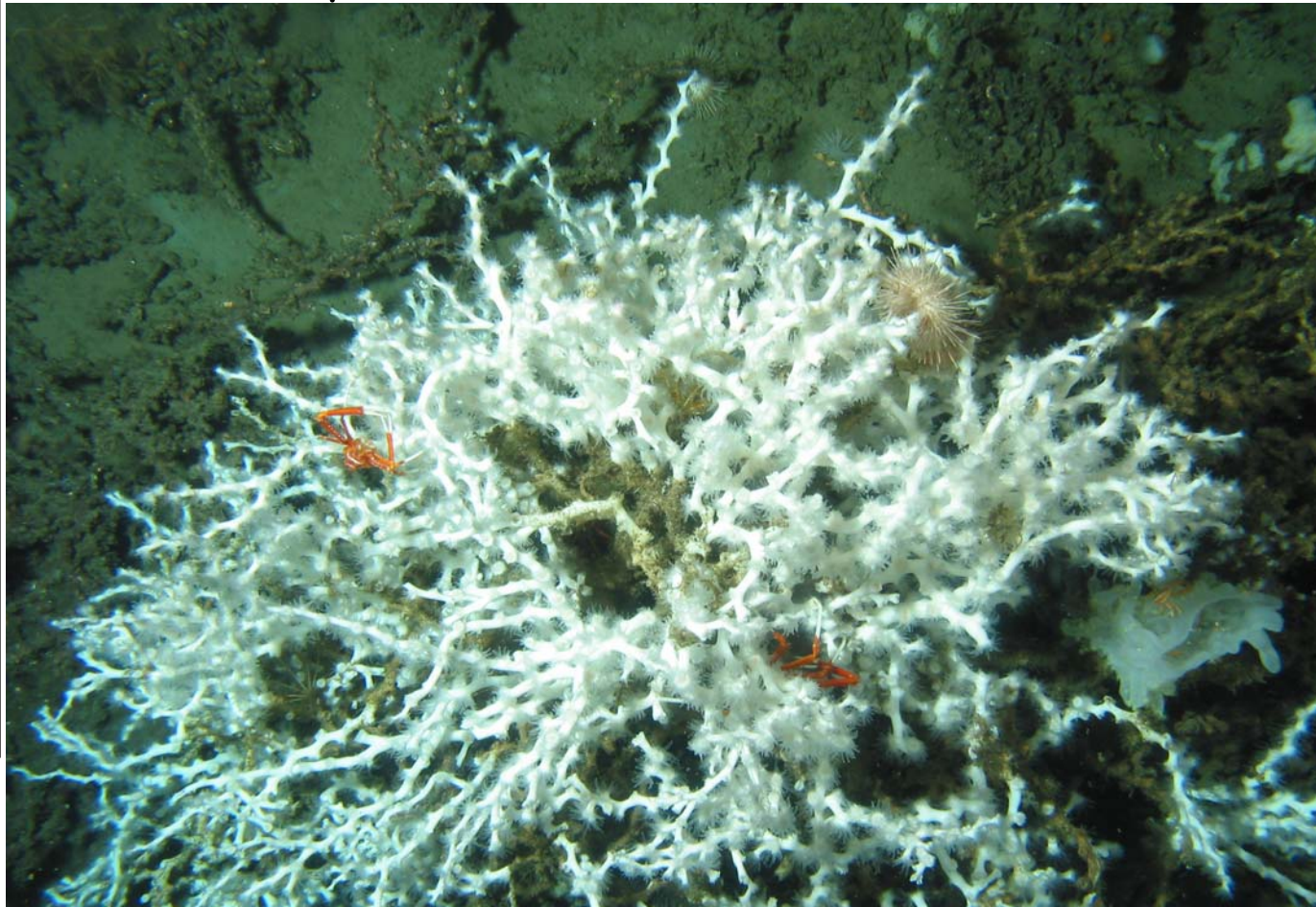
- Prevailing models of community organization and ecosystem dynamics do not include a genetic-based perspective.
- A genetic-based model would clearly place community and ecosystems ecology within an **evolutionary framework**.
- Essential for scaling up from population to communities and ecosystems. Genes are likely the best scalars because they are the result of natural selection and evolution.

Community Genetics Summary Points

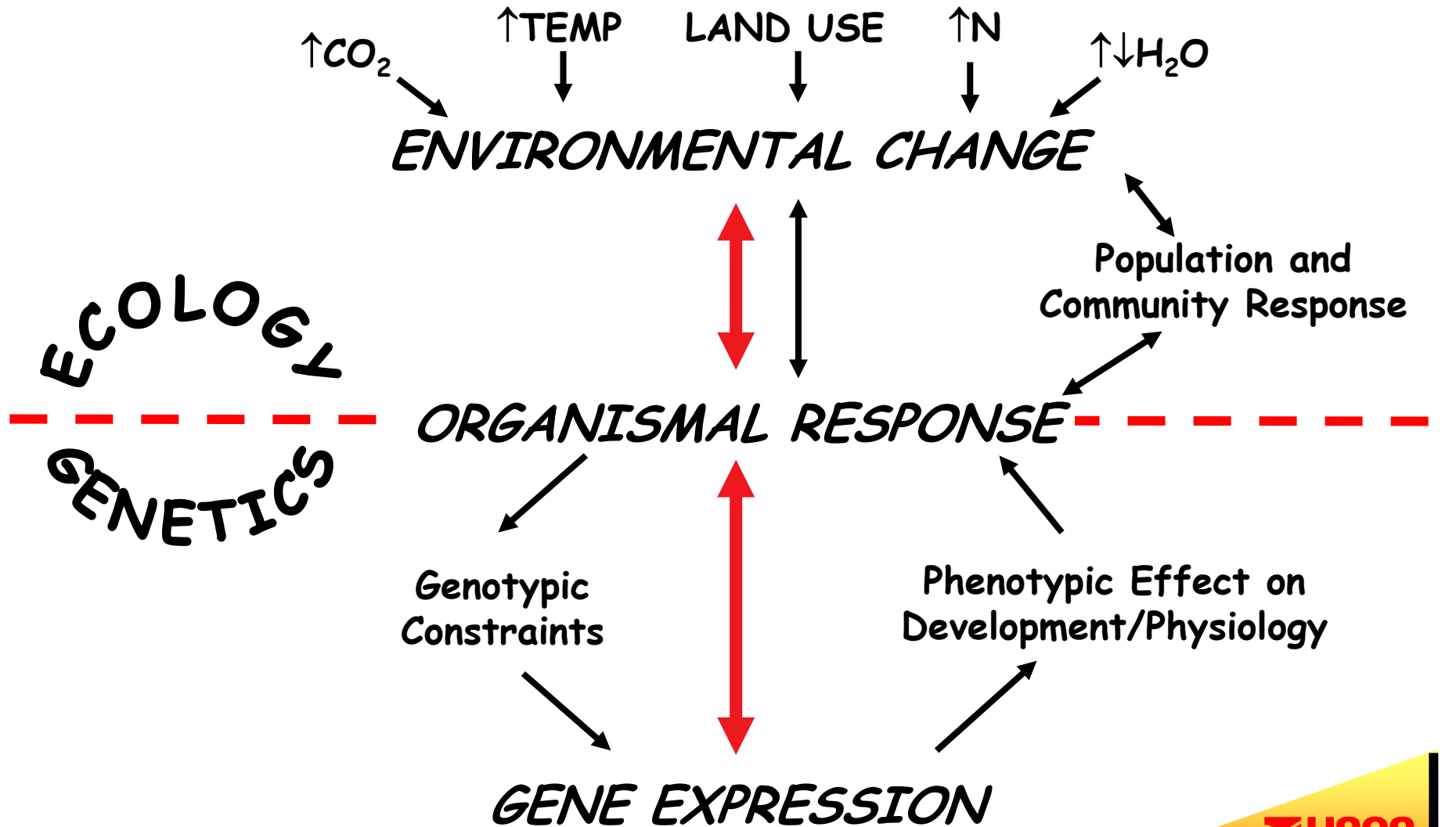
- In diverse systems, genes exhibit phenotypes that affect community structure & ecosystem processes.
- These phenotypes are likely to be most important when expressed in dominant and keystone species.
- Community structure and ecosystem processes can be heritable.
- To conserve dependent communities, we must preserve genetic diversity in dominant species.
- Emphasizes a community approach to conservation rather than a species approach.

Community Genetics Example

- Study the phylogeography or phylogenetics among the species coexisting within and among *Lophelia* bioherms (deep-sea coral reefs).



Ecological Genomics Conceptual Model



Ecological Genomics Applications

Functional Genomics

Determine whether genetic differentiation is adaptive or just an indicator of the impact stochastic processes have had on population structuring

Ecotoxicogenomics

Atlantic salmon smoltification - Identify up-regulated and down-regulated genes in response to herbicides, pesticides, paper mill effluent, low pH, and/or heavy metals

Genetic Engineering

Known risks - Engineered organisms pose risk to the environment in cases where:

- Lack of experience with the trait (e.g., increased growth) or DNA construct (e.g., an inhibitor) and its interaction with the target organism
- The organism may persist without human intervention
- Genetic exchange (i.e., introgression) is possible
- Trait confers a selective advantage

Parallels to Pesticides

A Perspective on humility and power

"The history of life on earth has been a history of interaction between living things and their surroundings. To a large extent, the physical form and the habits of the earth's vegetation and its animal life have been molded by the environment....Only within the moment of time represented by the present century has one species—man—acquired significant power to alter the nature of the world."

Rachael Carson

"The Obligation to Endure"

Silent Spring

Parallels to Pesticides: Questions

- Ethical
 - Social convenience vs. necessity
 - Humility vs. arrogance
 - Reversibility
 - Time and geographic impact
 - Readiness
- Technical
 - Efficacy
 - Drift and containment
 - Unintended & uncontrollable effects
- Management
 - Planning mechanisms & effectiveness
 - Risk assessment and management tools
 - Monitoring and evaluation
 - Response

Parallels to Pesticides

A Perspective on time

"For time is the essential ingredient; but in the modern world, there is no time. The rapidity of change and the speed with which new situations are created follow the impetuous and heedless pace of man rather than the deliberate pace of nature"

A Perspective on imbalances in the pace of science

"There are vast gaps in our knowledge....for the chemist's ingenuity in devising insecticides has long ago outrun biological knowledge of the way these poisons affect living organisms."

Rachael Carson

"The Obligation to Endure"
Silent Spring

Conservation Genetics – Dynamic and Adaptive

Direct Gene Insertion and Manipulation (allows for rapid selection of desirable or detrimental traits)

Transgenic (GH) salmon

- Faster growth
- Increased feed conversion efficiency
- Consume more feed
- Uptake more oxygen



Might show increased fitness, but gaps still exist in understanding key fitness parameters to allow assessment of the impact to wild populations.

Cultivated salmon escapes into the wild from farms pose ecological and genetic risks (**gene flow-introgression**) to native salmon stocks.

GEOs as a Conservation Tool

Gene constructs may be used to control the reproduction of invasive species

Example - Daughterless Gene Technology

Possible applications:
Asian swamp eels
Northern snakehead
Asian carp



Monopterus albus



Channa argus

Similar technology may be applicable to other invasive species (e.g., zebra mussels, nutria)

Advantages: no con-generics occur in North America for the construct to jump to other species.



Dreissena polymorpha



Myocastor coypus

Summary

Genetic variation is partitioned along the Species-Population-Individual continuum

Techniques exist to assess variation at all levels

Ignoring evolutionary processes and their impacts on genomes can result in misguided research and have detrimental effects on conservation efforts